ADDIS ABABA SCIENCE AND TECHNOLOGY UNIVERSITY

College of Architecture and Civil Engineering

Post Graduate study

Assessment of Asphalt Road Defects and Maintenances in Addis Ababa

An independent Project Submitted to the College of Architecture and Civil Engineering in partial fulfillment of the requirements of Master of Engineering in Civil Engineering (Construction Technology and Management)

Desta Eshete

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Assessment of Asphalt Road Defects and Maintenances Case :in Addis Ababa

By

Desta Eshete BSC in COTEM

January/2017

Approved by Board of Examiners

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Examiner (Internal)	**Signature**	**Date**
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Chair Person	**Signature**	**Date**

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Executive Summary

This study was conducted to asses asphalt defects (distresses) and also the existing maintenance practice on the Addis Ababa city roads. Furthermore, in order to evaluate the maintenance procedures, and also ensure the application of pavement management system and preventive maintenance.

Accordingly, asphalt road defects of three (3) roads that were span from Emperial Hotel to Gerji, from hana mariam to Kality total and from Kera to Mexico. These roads are old roads which have high extent of cracking, Rutting, Shoving, pot hole and patch deterioration. These old roads entertain from low to high traffic class category.

So as to signify the effect of distress, I have collected data based on the defect (distress) type, severity, and extent on these old roads selected randomly.

The study have used as a tool an interview, observation and my previous experience in the maintenance of Addis Ababa's asphalt roads.

This study reveals that the current practice of maintenance was traditional, not planned and scheduled, the maintenance practice did not follow what was set in ERA's specification for maintenance of asphalt roads 2003, even though, the pavement management department was structured, condition survey and road inventory were not done at all.

The current practice was costly and infeasible; hence, the Addis Ababa city roads authority has better understanding towards proper pavement management system, automated survey and proper maintenance procedure that meets the specification, even though finance and equipments had been the limitations.

The existing maintenance has a merit to meet emergent maintenance needs of vast areas of roads that were damaged as a result of the rainy season, but by not applying proper and scientific maintenance; the service life of the maintained roads became less, hence maintenance of those section of the roads became mandatory.

It can however, be argued that the transition from existing method to the modern and scientific maintenance method needs time and resource. Thus it can be achieved by training of workers, allocation of modern automated condition survey equipments, finance and skilled manpower to the work.

1.0 Introduction

Addis Ababa's ever-increasing demand for expansion of road in parallel to other infrastructural development is worthy. Road is the major contributor to the development of other infrastructural projects. Road classified as paved and unpaved roads based on surface types.

Addis Ababa currently has a road coverage of 4163Km, this road coverage encompasses roads built with modern design and also roads built with an old design .modern design is a design that considers the ever increasing demand of traffic, adequate cross fall, drainage facility, shoulder and utility spaces. One or many of these parameters may not be considered in the old design even structural adequacy met; because of this, the roads of Addis Ababa deteriorate early (before their design life).

The main causes of pavement failure before its design period are due to inappropriate cross fall provision for entertaining the surface runoff, Construction of roads without drainage. Furthermore, nonstandard design of roads for accommodating utility lines, inappropriate use of roads and drainages by the road users like maintaining vehicles on the road, dumping dirties in the manhole and in general lack of adequate pavement management systems.

Pavement management is the process of overseeing the maintenance and repair of a network of roadways.

Pavement management offers the potential for planned and scheduled maintenance there by creating improved road conditions and reduced pavement maintenance costs, while maintaining streets and roads in good condition (at a relatively low cost) rather than allowing asphalt pavements to deteriorate to the point where extensive rehabilitation or reconstruction becomes necessary.

Asphalt road defects are defects that are visible on the surface of the asphalt, those are surface cracks, patching and potholes, surface deformation and miscellaneous distresses.

Asphalt concrete road construction needs proper care in the provision of quality materials as per the specification, the right equipment and skilled and specialized professionals for constructing and supervising it.

Application of poor materials is one of the major problem existed in the current asphalt road construction. To mention some of the materials Asphalt, which is one of the ingredients that are prime importance in binding the asphalt concrete, this material should be of proper grade, quality that fulfills the required (specified) test criteria of AASHTO.

The aggregates are also the other important ingredients that play a very important role in resisting the traffic load and transferring the load to the underneath layer through its interlocking effect.

Aggregates for asphalt concrete have its Chemical properties that determine how well asphalt cement adhere with an aggregate.

In addition to this aggregates have physical properties that express its direct effect on how an aggregate performs as either a pavement material constituent or by itself as a base or sub base material.

Furthermore, its gradation and size is also the most influential characteristics that influence how it performs as pavement materials.

In asphalt concrete gradation helps to determine almost every property including stiffness, stability, durability, permeability, workability, fatigue resistance, frictional resistance and resistance to moisture damage. Asphalt concrete roads extend life, if properly and timely maintained up the severity and extent of the defect.

Asphalt Maintenance can be categorized as periodic and routine maintenance. Maintenance is required to reduce vehicle operating cost, Congestion /loss of time, restrictions/ diversions for bridges, Accident costs and reconstruction cost.

1.1 Statement of the problem

Asphalt road distresses (defects) in Addis Ababa are common phenomenon on many of the roads that are old and sometimes on the newly constructed roads.

For those defects drainage problem has a major part in contributing for pothole and patch deterioration. In addition to this, proper maintenance and workmanship were also the causes for early failure and shortening of the service life. As a whole, pavement management system were not practiced, so as to manage each asphalt road network through an inventory and condition survey of each and every network roads based on their type, severity and extent to prioritize and apply preventive maintenance measure as it need be.

As a result of this, maintained asphalt roads fail early, prolonged traffic congestion and delay cost due to potholes and structural damages of the asphalt roads in the city. Furthermore, it increased operation cost of the traffic.

Therefore, it is the interest of this research to asses existing situation to identify potential problems and recommend possible solution that can be practiced in the Addis Ababa city roads maintenance.

1.2 Objectives

1.2.1 General Objective

- To asses asphalt defects and their maintenances in Addis Ababa.

1.2.2 Specific Objective

- To signify the causes of Asphalt defect in Addis Ababa and its remedies.
- To asses which type of failure was resulted due heavy traffic load?
- To asses planned and scheduled maintenance practiced.
- To check the use of modern and automated condition survey equipments on the asphalt road maintenance.
- To signify the effect of preventive maintenances.
- To asses which type of maintenances was in use?
- To asses also the maintenance procedures
- To evaluate Bitumen spraying rate

2.0 Literature review

Asphalt pavements are maintained by the use of hot mixed asphalt concrete that is mixed aggregate with asphalt cement so as to enhance the durability of the asphalt concrete, ease of maintenance, and for early opening to traffic after maintenance.

The single most important factor that affects the long-term durability of a hot-mix asphalt (HMA) pavement is the density of the mix that is achieved by the contractor at the time of construction. The density of a material is defined as the weight of the material, which occupies a certain volume of space. The compaction process causes the asphalt-concrete mix to be compressed and its volume reduced. As the density of the HMA material increases, the air-void content of the mix decreases (they are inversely proportional to each other). Properly designed, a HMA mix should have air-void content in the range of 3% to 5%.

If the compacted mix has a high air-void content (greater than 8%), the mix will not perform as well under traffic; Similarly, if the compacted mix has a low air-void content (less than 3%), the mix will be susceptible to permanent deformation or rutting and also to distortion under the applied traffic loads. Thus, for the mix to perform as expected, the contractor must be able to compact the mix to the desired level of density or air-void content.

The density of the asphalt-concrete mix controls its durability. All of the following factors are related to the air-void content of the HMA material: fatigue life; permanent deformation; oxidation; moisture damage; distortion; and disintegration.

As the air void of the HMA decreases, the fatigue life or number of repetitions of load to failure of that mix increases. Previous tests have shown that reducing the air-void content of a given asphalt-concrete mix from 8% to 5%; can double the fatigue life of the pavement. Thus, for a given thickness of HMA as part of the pavement structure, the ability of the mix to carry load can be increased significantly when the mix is compacted to lower air-void content.

The amount of permanent deformation or rutting that develops under load in a HMA material also is directly related to the air-void content of the mix. As the air-void content decreases, the amount of rutting that will occur in that mix also decreases. If the mix design is proper, a well compacted mix will not rut under the action of the traffic loads. If the mix design is deficient in some aspect, proper compaction of the mixture can still significantly reduce the amount of rutting and lateral distortion that will occur under repeated load applications. If, however, the air-void content of the mix is reduced to less than 3%, an increase in the rate of rutting of the mix can result. With time, the asphalt-cement binder in an asphalt-concrete mix will oxidize and become more brittle. This oxidation or aging process causes the asphalt cement to decrease in penetration and increase in viscosity. The rate of oxidation is directly related to the air-void content of the mix. The lower the air-void content, the less quickly the HMA material will age and become stiffer.

Moisture damage or stripping occurs when water is able to enter the mix and, under the repetitive action of traffic, works its way in between the asphalt coating on the aggregate and the surface of the aggregate. The degree of moisture damage is primarily related to the characteristics of the aggregate used in the mix but also is directly related to the air-void content of the mix. As the air-void content in the mix decreases, the amount of moisture damage also decreases. Indeed, a mix that may strip badly at an air-void content of 8% may not suffer any moisture damage if it can be compacted to an air-void content below 4%.

Distortion or shoving is the displacement of the mix, typically in the longitudinal direction, under the action of traffic. Distortion is primarily related to the design and properties of the mix but also is related to the air-void content.

For a given mix, a decrease in the air-void content at the time of construction will decrease the amount of distortion that the mix will undergo when exposed to traffic loads, particularly stopping or turning movements. An increase in the density of the mix (a decrease in the air-void content) will increase the internal stability and strength of the mix and may significantly reduce the amount of distortion that occurs under load.

Disintegration or raveling is directly related to the air-void content of the mix. If a mix is properly compacted (to an air-void content of 8% or less), the mix generally will not ravel if the asphalt content is correct. If the same mix is compacted to high air-void content, however, major raveling may occur under the applied traffic loads. As the air-void content of the mix decreases, the amount of raveling also will decrease.

An asphalt-concrete mix must be fully compacted before it cools to a temperature of about 175 F. At temperatures above this value, the mix is normally still warm enough for the compaction equipment to reorient the aggregate particles into their densest configuration. Below that temperature, however, the mix is generally too stiff to increase in density any significant amount with continued rolling, although roller marks can often be removed below this compaction cutoff temperature.

The mix must, therefore, be compacted while it is still hot. Five factors directly affect the rate of cooling of the asphalt concrete mix when that material is placed on top of another existing layer of the pavement structure. Those variables are: air temperature; base temperature; mix lay down temperature; layer thickness; and wind velocity.

All other factors being equal, as the ambient air temperature increases, the time available for compaction also increases. The mix will take longer to cool to the cutoff temperature of 175 F on a warm day than on a cool day. An increase in the air temperature allows more time for the compaction equipment to achieve the desired density level in the mix.

More importantly air temperature in the rate of cooling of the HMA mix is the temperature of the surface of the layer on which the new mix is placed. It is well known that heat in an asphalt concrete layer is lost in two directions. The surface of the mixture cools as heat is transferred to the air. The bottom portion of the mixture also cools as heat is transferred to the underlying base material. There is more rapid cooling of the mix downward into the base than upward into the ambient air.

Base temperature-the temperature of the layer on which the new asphalt concrete mix is placed-is actually more important than air temperature in determining the time available for compaction. An increase in the base temperature allows more time for compaction.

As the temperature of the mix coming out from under the paver screed increases, the time available for compaction also increases. A mix placed at a temperature of 300 F, for a given lift thickness and other environmental factors, will take longer to cool to the cutoff temperature of 175 F, than will the same mix placed at a temperature of 250 F.

Probably the most important factor in the rate of cooling of an asphalt concrete mix is the thickness of the layer being placed and compacted. As the thickness of the layer increases, the time available for compaction also increases. It takes considerably longer for a 3-in. thick layer of HMA to cool to the cutoff temperature of 175 F than for a 1-in. layer to cool to the same temperature.

The cooling time is not directly proportional to the lift thickness but is geometrically proportional. For example on a 40 F day with the temperature of the base at the same value, a 3-in. thick layer of HMA placed at a temperature of 250 F will take 19 minutes to cool from the lay down temperature to the cutoff temperature of 175 F. On the same 40 F day, with the same base temperature and for the same mix lay down temperature of 250 F, a 1-in. thick HMA layer will cool to the cutoff temperature in only 3 minutes.

A thin lift of asphalt-concrete mix will cool more quickly when exposed to a high wind velocity than when there is little or no wind. Wind has a much greater effect on the surface of the mix than at various depths within the HMA layer. A strong wind can cause the surface to cool so rapidly that a crust will form. This crust must be broken down by the rollers before the compaction process can be accomplished. The higher the wind velocity, the less time available for compaction ; all other factors being constant. According to distress identification manual for long term pavement performance program (LTPP); Asphalt concrete-surfaced pavements (ACP), including ACP overlays on either asphalt concrete (AC) or Portland cement concrete (PCC) pavements.

Asphalt distresses has been grouped into five categories based on the distress identification manual. These are :-

2.1 Cracking

2.2 Patching and Potholes

2.3 Surface deformation

2.4 Surface defects

2.5 Miscellaneous distresses

Asphalt pavement road Cracks are common phenomena from the construction up to service life of the pavement. Those cracks can be recognized visually. In order to identify the type of cracking and its probable causes, the following illustrative description has been made and also Measurement of crack width is to be taken in order to evaluate the Severity level of the crack.

2.1.1 Fatigue cracking

The Occurrence of this crack is on areas subjected to repeated traffic loadings (wheel paths). It Can be a series of interconnected cracks in early stages of development. Develops into many-sided, sharp-angled pieces, usually less than 0.3 meters (m) on the longest side, characteristically with a chicken wire/alligator pattern, in later stages.

Must have a quantifiable area.

Severity Levels

2.1.1.1 Low

An area of cracks with no or only a few connecting cracks; cracks are not spalled or sealed; pumping is not evident.

2.1.1.2 Moderate

An area of interconnected cracks forming a complete pattern; cracks may be slightly spalled; cracks may be sealed; pumping is not evident.

2.1.1.3 High

An area of moderately or severely spalled interconnected cracks forming a complete pattern; pieces may move when subjected to traffic; cracks may be sealed; pumping may be evident.

2.1.2 Block cracking

The type of cracking visible in a rectangular pattern. This pattern range in size from approximately 0.1m2 to 10 m2. According to ERA specification 2003 also it is interconnected cracks in a bituminous road surface forming a serious of large polygon usually with sharp corners or angles.

Severity Levels

2.1.2.1 Low

Cracks with a mean width ≤ 6 millimeters (mm) , or sealed cracks with sealant material in good condition and with a width that cannot be determined.

2.1.2.2 Moderate

Cracks with a mean width > 6 mm and ≤ 19 mm; or any crack with a mean width ≤ 19 mm and adjacent low severity random cracking.

2.1.2.3 High

Cracks with a mean width > 19 mm ; or any crack with a mean width ≤ 19 mm and adjacent moderate to high severity random cracking.

2.1.3 Edge Cracking

This type of crack occurs only to pavements with unpaved shoulders. Crescent-shaped cracks or fairly continuous cracks which intersect the pavement edge and are located within 0.6 m of the pavement edge, adjacent to the shoulder. Includes longitudinal cracks outside of the wheel path and within 0.6 m of the pavement edge.

Severity Levels

2.1.3.1 Low

Cracks with no breakup or loss of material.

2.1.3.2 Moderate

Cracks with some breakup and loss of material for up to 10 percent of the length of the affected portion of the pavement.

2.1.3.3 High

Cracks with considerable breakup and loss of material for more than 10 percent of the length of the affected portion of the pavement.

2.1.4 Longitudinal Cracking

Cracks predominantly parallel to pavement centerline. Location within the lane (wheel path versus non-wheel path) is significant.

Severity levels

2.1.4.1 Low

A crack with a mean width ≤ 6 mm; or a sealed crack with sealant material in good condition and with a width that cannot be determined.

2.1.4.2 Moderate

Any crack with a mean width > 6 mm and ≤ 19 mm; or any crack with a mean width ≤ 19 mm and adjacent low severity random cracking.

2.1.4.3 High

Any crack with a mean width > 19 mm; or any crack with a mean width ≤ 19 mm and adjacent moderate to high severity random cracking.

2.1.4. A) Wheel Path Longitudinal Cracking

Record the length in meters of longitudinal cracking within the defined wheel paths at each severity level.

Record the length in meters of longitudinal cracking with sealant in good condition at each severity level.

Note: Any wheel path longitudinal crack that has associated random cracking is rated as fatigue cracking. Any wheel path longitudinal crack that meanders and has a quantifiable area is rated as fatigue cracking.

2.1.4. B) Non-Wheel Path Longitudinal Cracking

Record the length in meters of longitudinal cracking not located in the defined wheel paths at each severity level.

Record the length in meters of longitudinal cracking with sealant in good condition at each severity level.

2.1.5 Reflection Cracking At Joints

Cracks in asphalt concrete overlay surfaces that occur over joints in concrete pavements.

Note: The slab dimensions beneath the AC surface must be known to identify reflection cracks at joints.

Severity Levels

2.1.5.1 Low

An unsealed crack with a mean width ≤ 6 mm; or a sealed crack with sealant material in good condition and with a width that cannot be determined.

2.1.5.2 Moderate

Any crack with a mean width > 6 mm and ≤ 19 mm; or any crack with a mean width ≤ 19 mm and adjacent low severity random cracking.

2.1.5.3 High

Any crack with a mean width > 19 mm; or any crack with a mean width ≤ 19 mm and adjacent moderate to high severity random cracking.

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2.1.6 Transverse Cracking

Cracks that are predominantly perpendicular to pavement centerline.

Severity Levels

2.1.6.1 Low

An unsealed crack with a mean width ≤ 6 mm; or a sealed crack with sealant material in good condition and with a width that cannot be determined.

2.1.6.2 Moderate

Any crack with a mean width > 6 mm and ≤ 19 mm; or any crack with a mean width ≤ 19 mm and adjacent low severity random cracking.

2.1.6.3 High

Any crack with a mean width > 19 mm; or any crack with a mean width ≤ 19 mm and adjacent moderate to high severity random cracking.

2.2 Patch/Patch Deterioration

Portion of pavement surface, greater than 0.1 m2, that has been removed and replaced or additional material applied to the pavement after original construction.

Severity Levels

2.2.1 Low

Patch has, at most, low severity distress of any type including rutting < 6 mm; pumping is not evident.

2.2.2 Moderate

Patch has moderate severity distress of any type or rutting from 6 mm to 12 mm; pumping is not evident.

2.2.3 High

Patch has high severity distress of any type including rutting > 12 mm, or the patch has additional different patch material within it; pumping may be evident.

2.2.1 Potholes

Bowl-shaped holes of various sizes in the pavement surface. Minimum plan dimension is 150 mm.

Severity Levels < 25 mm deep expressed as Low, 25 mm to 50 mm deep expressed as Moderate, > 50 mm deep expressed as High.

2.3 Surface Deformation

2.3.1 Rutting

A rut is a longitudinal surface depression in the wheel path. It may have associated transverse displacement.

Severity Levels

Not applicable. Severity levels could be defined by categorizing the measurements taken. A record of the measurements taken is much more desirable, because it is more accurate and repeatable than are severity levels.

2.3.2 Shoving

Shoving is a longitudinal displacement of a localized area of the pavement surface. It is generally caused by braking or accelerating vehicles, and is usually located on hills or curves, or at intersections. It also may have associated vertical displacement.

Severity Levels

Not applicable. However, severity levels can be defined by the relative effect of shoving on ride quality.

2.4 surface defects

Bleeding

Polished Aggregate

Raveling

2.4.1 Bleeding

Excess bituminous binder occurring on the pavement surface, usually found in the wheel paths. May range from a surface discolored relative to the remainder of the pavement, to a surface that is losing surface texture because of excess asphalt, to a condition where the aggregate may be obscured by excess asphalt possibly with a shiny, glass-like, reflective surface that may be tacky to the touch.

Severity Levels

Not applicable. The presence of bleeding indicates potential mixture related performance problems. Extent is sufficient to monitor any progression.

Note: Preventative maintenance treatments (slurry seals, chip seals, fog seals, etc.) sometimes exhibit bleeding characteristics. These occurrences should be noted, but not rated as bleeding.

2.4.2 Polished Aggregate

Surface binder worn away to expose coarse aggregate.

Severity Levels

Not applicable. However, the degree of polishing may be reflected in a reduction of surface friction.

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2.4.3 Raveling

Wearing away of the pavement surface caused by the dislodging of aggregate particles and loss of asphalt binder. Raveling ranges from loss of fines to loss of some coarse aggregate and ultimately to a very rough and pitted surface with obvious loss of aggregate.

Severity Levels

Not applicable. The presence of raveling indicates potential mixture related performance problems. Extent is sufficient to monitor any progression.

2.5 Miscellaneous distresses

2.5.1 Lane-To-Shoulder Drop-off

Difference in elevation between the traveled surface and the outside shoulder. Typically occurs when the outside shoulder settles as a result of pavement layer material differences.

Severity Level

Not applicable. Severity levels could be defined by categorizing the measurements taken. A record of the measurements taken is much more desirable, however, because it is more accurate and repeatable than are severity levels.

2.5.2 Water Bleeding And Pumping

It is seeping or ejection of water from beneath the pavement through cracks. In some cases, detectable by deposits of fine material left on the pavement surface, which were eroded (pumped) from the support layers and have stained the surface.

Severity Levels

Not applicable. Severity levels are not used because the amount and degree of water bleeding and pumping changes with varying moisture conditions.

Note. The combined length of water bleeding and pumping cannot exceed the length of the test section.

Types Of Defects And Their Causes

There are many types of defects appearing on the asphalt road, these defects have their own causes and effects on the asphalt roads. According to distress identification manual for long term pavement performance program (LTPPP) US department of state Federal High way administration June, 2003, it has been tried to list the types of asphalt defects and the possible remedies in the following table-1.

Table-1 Types of asphalt road distresses, its possible causes and remedies

Item no.	Type	Possible Causes	Remedies
1.0	Cracking		
	1.1 Fatigue Cracking	-Insufficient strength/ weak surface, base and sub grade. -End of pavement life. - Excessive traffic load. -Too heavy loads. -Poor Drainage	-Remove the defected area and replace. -Remove, mill and Overlay
	1.2 Block cracking	-Old and dried out mix -Mix was placed too dry -Fine aggregate mix with low penetration asphalt and absorptive aggregates. -Aggravated by low traffic volume. -Propagation of fatigue crack if not maintained early.	Any surface treatment (Chip seal or Slurry seal) or Thin over lay.
	1.3 edge Cracking	-Soil movement beneath pavement. -Lack of lateral support. -Shrinkage of drying out soil. -Weak base or sub grade layer	-Improve drainage by removing the source that trap the water -Fill the crack by asphalt emulsion

Item No.	Type	Possible Causes	Remedies
		-Poor drainage -Frost heave -Heavy traffic or vegetation along edge	Slurry or light grade of asphalt mixed with fine sand -Provide side drainage ditches. - Crack seal or fill.
	1.4 Longitudinal Cracking	-Poorly constructed paving joint crack -Shrinkage of the asphalt layer. -Daily temperature cycling. -Cracks in underlying layer that reflect up through the pavement. -Longitudinal segregation caused by improper operation of paver.	-Improve drainage by removing the source that traps the water. -Seal crack or fill with asphalt emulsion slurry or light grade of asphalt mixed with fine sand. -Provide side drainage ditches. -Crack seal / Fill
	1.5 Reflection cracking	-Existing cracks or joints in the underlying structure -Concrete slab movement.	-Crack filling. -Extensive pre-overlay repair. -Saw and seal -Extensive pre-

Item no.	Type	Possible Causes	Remedies
			-Extensive pre-over lay repair. -Crack and seat -Saw and Mill
	1.6 Transverse (Thermal Cracking)	-Contraction and expansion of pavement layer with changing Temperatures.	-Crack filling. -Full Depth reclamation -Thick overlay.
2	Patching and pot hole		
	2.1 Patch deterioration	-Poor bonding to existing pavement -Improper compaction. -Poor materials. -Propagation of original distress.	-Remove and replace (Re-patch). -Asses original distress.
	2.2 Pot hole	-Raveling of cracks -Moisture damage -Freeze- Thaw -Insufficient strength. -Poor surface material mixture	-Patch

Item no.	Type	Possible Causes	Remedies
3.0	Surface Deformation		
	3.1 Rutting	-Low air void (asphalt content too high). -Smooth rounded aggregate (excessive amounts of natural sand). -Excess Dust	-Remove / Replace 10cm -Micro surfacing
	3.2 Shoving	-Unstable mix -Braking, stopping or accelerating traffic. -Slippage between layers.	-Remove and replace. -Thick overlay
4	Surface Defects		
	4.1 Bleeding	-Too high asphalt content. • Too rich a plant mix. • Improperly constructed seal coat. • Too heavy prime or tack coat.	-Sand Bolt -Micro-surfacing. -Seal coat.

Item no.	Type	Possible Causes	Remedies
	4.2 Polished Aggregate	-Soft Aggregate -Heavy Traffic	-Seal Coat. -Micro-Surfacing. -Thin over lay.
	4.3 Raveling	-Asphalt binder unable to hold aggregate in place. • Dusty aggregates. • Segregation • Low in-place density • Aged asphalt binder • Stripping	-Seal coat -Micro-surfacing -Thin over lay.
5	Miscellaneous distresses		
	5.1 Lane-Shoulder drop off	Differences in materials used for lane and shoulder -Differential settlements. -Insufficient compaction of base.	-Wedge/ Leveling over lay -Micro -surfacing.
	5.2 Water bleeding and pumping	-Cracks -Inadequate drainage	-Full depth patch -Crack seal

3.0 Research Methodology

3.1 Research Design

The main strategy followed was to formulate research design. Then after data and information sources were obtained up on the formulated research design. Based on the data and information sources, the research instruments were decided.

In the end, the required data were collected and analyzed. Finally, available documentary sources of local and international were reviewed for cross-checking the validity and conformity of the information obtained through the overall research work.

A descriptive and empirical survey design was used in the study. It was tried to collect data from AACRA's asphalt maintenance workers and relevant construction department head to determine existing practice of maintenance of Addis ababa asphalt roads.

The variable in this study is the difference between the current practice of asphalt road maintenance in Addis Ababa and the applicability of distress identification and standard asphalt road maintenance manuals.

This survey based research has been selected to demonstrate the existing asphalt distress with its type, severity and extent and also the application of preventive maintenance against the current scientific and modern maintenance practice done internationally.

3.1.1 Data And Information Sources

The information were drawn from AACRA's construction director, maintenance foreman and bitumen sprayer. Purposive sampling used to evaluate the type of defects observed on the old asphalt roads; furthermore, the severity and extent was also evaluated. In addition to this, the type of traffic using the roads

3.1.2 Research Instrument

One of the instruments that were used in this research was an interview with the construction director of AACRA, maintenance team foreman, and bitumen sprayer. The other is observation, from this it can dictate the possible cause and effects of the current maintenance practice. The third instrument used was my own experience while working in the maintenance team as a construction supervisor**.**

3.1.3 Data Collection And Analysis

This study used primary data from the above mentioned firm and workers.

The primary data were collected through interviews, observation and personal experience. The interview were supposed to explain the current maintenance practice in relation to the procedure, the technique and conformance of modern and scientific methods of Addis Ababa roads. Furthermore, equipment, materials and application rates were also discussed. In addition to this, type, severity and extent of asphalt defects appeared on the selected roads observed, evaluated and measured.

On the data analysis, it has been used qualitative data analysis based on the current practice in the maintenance of the Addis Ababa asphalt road and on the standard maintenance manual that was issued for the maintenance of asphalt roads and also application of the pavement management system.

The study location (area) was selected based on the oldness of the roads which were thought to had considerable defects (distresses) and also heavy loaded trafficked roads.

The data was also analyzed using qualitative and quantitative analysis. The analysis is based on the distress identification and standard maintenance manual of asphalt roads. Furthermore, application of planned and scheduled maintenance was also analyzed.

Generally, the study comprises the following stages;

1.0 The principal activities were to know the current practice in the maintenance of Addis Ababa asphalt roads.

2.0 Identification of the principal sources of information, highlighting the main headings of the problem, and formulation of the problem.

3.0 Preparation of research methodology, both research strategy and data collection.

4.0 Design appropriate research instruments

5.0 International and local asphalt maintenance and distress identification manual reviews.

6.0 Summarizing data gathered

7.0 Analysis of the current practice of asphalt maintenance in Addis Ababa based on all the materials gathered application of distress identification manual and standard specification for the maintenance of asphalt roads.

8.0 Critical review of the study and its findings, as well as its discussion and recommendation.

3.1.4 Rating Of Asphalt Distresses

The rating of asphalt distresses was done according to Distress identification manual for long term pavement performance program (LTPPP) and Manual for condition rating of flexible asphalt pavement, asphalt distresses first identified up on its type then after rated based on its severity and extent. The following table shows asphalt distress ratings of observed defects during data collection.

Table-2 Rating of asphalt distresses

Item no.	Type of distress	Unit of measure	Severity	Extent
1	Cracking	M2	<=6mm-Low >6mm<=19mm-Moderate >19mm- High	
2	Patch Deterioration	M2	< 6mm-low with no pumping-Low >6mm <12mm with no pumping- Moderate >12mm with pumping- High	
3	Pot hole	M2	< 25mm – Low 25 to 50mm deep-Moderate >50mm deep- High	
4	Rutting	Milimeter	< 6mm- Low 6 to 12 mm –Moderate >12mm- High	
5	Shoving	M2	Expressed in terms of ride quality	
6	Raveling	M2	Expressed in terms of the raveled surface condition	

3.2 Limitation Of The Study

This study attempts to assess the current asphalt maintenance in Addis Ababa and to evaluate the standard specification of asphalt road maintenance, distress identification manual and application of pavement management systems. Every attempt has been made to seek information from relevant stakeholders and to review different standard mauals.

However, this study needs forensic investigation in order to let the research be more informative, exhaustive and reliable. Hence, some findings of the study are based on the selected sample roads.

The other important limitation was the mismatch of answers of the interviewees to the same question

4.0 Current Practice In The Maintenance Of Asphalt Pavements In Addis Ababa

In Addis Ababa, it has been noted that asphalt roads constructed partially and maintained fully by the Addis Ababa city roads Authority (AACRA). This maintenance activities was led by the maintenance team.

Out sourcing of new construction projects is also done by local and foreign contractors, but maintenance of the asphalt roads still done on force basis except consultancy services.

Globally, maintenance of asphalt pavements need uniform, standard and consistent definition of defects so as to have common language in the identification of distresses. Furthermore, it is mandatory to have standard technical specification for asphalt road maintenances for different asphalt distresses and causes so as to attain uniform quality standard, efficiency and safety and also helpful for contracting out maintenance works. In addition to this, it is helpful for accurately costing or pre-estimating, prioritizing and budgeting the maintenance activities.

Currently, the asphalt maintenances need to be cost and time efficient. Furthermore, it should also be good quality so as to do this, it is recommendable to asses the defects (distresses) of asphalt pavement and its maintenances in Addis Ababa. For this reason three roads were sampled to analyze the asphalt defects, probable causes and maintenance strategy required. These three roads are From Emperial Hotel to Gerji, From Hana Mariam (on the ring road outer lane) to kality total and from Kera to Mexico. The selection of these roads depended on two reasons :-

1.0 The roads are old, therefore it has many defects (distresses).

2.0 The roads entertain from low to high traffic class vehicles.

4.1 From Imperial Hotel to Gerji

4.1.1 The existing asphalt defects (distresses)

The road is quite old, congested by traffic of low to medium vehicles and it is 12m wide, therefore, the contact time between the tire and the road is low, as a result of this the road's life time extends.

Since the road drainage are partially damaged, some length blocked by trash and the rest are functional but on poor condition due to lack of attention by respected authority.

As a result of this, during rainy season the flood do not only drain within the drainage but also it stays on the pot hole of the asphalt pavement; to this effect the stagnant water on the asphalt pavement penetrates in to the surface results in structural damage and deterioration of the asphalt surface due to slopping or cambering and different distresses problem of the pavement, this is seen on the figure-21, 22, 23 and 24

On some part of this road the drainage line and manhole gutters are functional but the surface water on the asphalt pavement could not directed towards the manhole due to slope problem of the road , this can be best illustrated on figure-21 & 26.

In general, the road on this section is better than other road samples, even though, potholes creation due to slope problems of the crown to shed surface runoff towards the drainage line. In order to illustrate this it has been tried to collect data based on the type of distress, extent and severity. Furthermore, the quantity of materials and feasible maintenance alternatives.

Figure-19 Photo courtesy of AACRA Pot holes high severity and low extent

Figure-20 Photo courtesy of AACRA Potholes of high severity and extent

Figure-21 Photo courtesy of AACRA Slope and crown problem of the road for stagnation of rain water

Figure-22 Photo courtesy of AACRA Surface damage of asphalt due drainage blockage

Figure-23 Photo courtesy of AACRA Surface damage due to drainage blockage and cambering problem

Figure-24 Photo courtesy of AACRA, Structural damage of the road due to penetration of the stagnant water on pot hole of high severity and extent

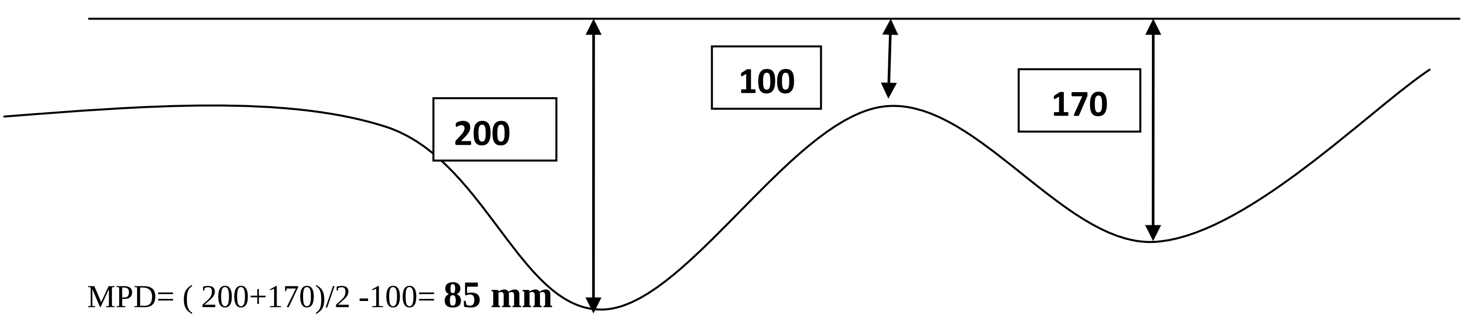
Figure-25 Photo courtesy of AACRA, Pot hole of high severity and extent and also slope problem of the crown

Figure-26 Photo courtesy of AACRA, pot hole and asphalt surface damage and slope problem around Gerji

The following table 3 shows the road condition survey data performed on this road

Item no	Type of distress	unit	Quantity	Severity	Extent	Feasible maintenance alternative
1	Pot Hole	M2	16	High	low	Cut and saw mill and Patching
2	Asphalt Surface Damage	M2	40	High	Moderate	Rehabilitation of the surface
3	Slope problem of the crown	ML		High	High	Complete surface rehabilitation
4	Rutting (Non wheel path)	MPD	85	High	Low	Full depth reclamation

Rut depth measurement using Mean profile Depth (MPD).



MPD= (200+170)/2 -100= **85 mm**

Figure-29 Rutted road section depth measurement

As can be seen from the road condition survey data of table 1, one can observe that the causes for these damage (deterioration) were simple and less cost if timely maintained, inspected periodically and performed condition survey with data base.

4.1.2 Improvement to the existing asphalt pavement distress

Since the road is aged more than 15 years, it is inevitable to observe many types of asphalt distresses on the surface of the pavement. For proper and timely maintenance of the asphalt pavement condition survey plays an important role.

Next to this, identification of the asphalt distresses based on distress identification manual so as to come to the possible causes of the distress, sometimes it needs forensic investigation to accurately determine the type of distress.

The defects on this section of the road are mortar damage of the masonry wall of the open ditch drainage, this is due to lack of attention of the respected Authority for early action. Furthermore, drainage blockage resulted from lack of awareness of the public not to dump rubbish in the drainage lines and also due to lack of periodic inspection of the lines.

As it has been mentioned previously due to the oldness of the road, the road camber did not properly direct surface runoff towards the drainage line, as a result of this water accumulates on the asphalt pavement; this water penetrates into the weaker portion of the asphalt pavement and results in pothole formation and surface damage of the asphalt, therefore the asphalt surface should be scarified or ripped by grader and new asphalt surface of properly cambered as per the standard permit (2.5%) should be re-constructed.

4.2 From Kera to Mexico

4.2.1 Existing Condition

This road is also an old and highly congested with small to medium class traffic category. The road is also two way two lane and 6m of each lane It is also provided with closed pipe drainage facility with inspection manhole and gutter to receive surface runoff and direct to the main drainage system via the manhole.

Some of the manholes are blocked by dirt, this blockage coupled with the slopping problem of the road to direct the surface runoff towards the manhole gutter. As a result of this, surface runoff runs on the asphalt pavement and becomes stagnant on the asphalt pavement. In addition to this, due to drainage blockage by trash, the water over flow from the manhole and drain on the asphalt pavement, oughting to this, the water standing on the asphalt penetrated into the existed surface cracks, the cracks developed to pothole of high severity and complete damage to the surface. This is the co-incidence around Kera down to Total fuel station on the road that directs to Mexico. This road repeatedly patched year by year but the problem was also slopping problem of the surface to direct the surface runoff towards the manhole gutter.

As it has been seen on the section of the road that extends from Asmara Hotel towards Genet Hotel (towards Mexico) Shoving or slipping was a phenomenon, this shoving may be resulted due to excess rate of application of tack coat or use of poor asphalt mix while overlaying. This shoving happened on the uphill road during hot weather condition coupled with traffic braking.

When we say excess application of tack coat, it is to explain that the rate of application of tack coat for maintenance was specified. According to ERA specification for maintenance of asphalt road 2003, it is 0.15 -0.2 kg per square meter. If the application rate exceeded this shoving or slippage is an incident especially on the roads that are uphill or downhill due to traffic braking.

Asphalt mix problem resulted due to problem of proportion of the ingredients while mixing, Use of excess asphalt in the mix or use of finely sized aggregate in the mix.

Figure-27 Photo courtesy of AACRA Potholes of high severity around Kera Total fuel station

Figure-28 Photo courtesy of AACRA Potholes of high severity around Kera Total fuel station

The following table 4, shows the road condition survey data performed on this road section

Item no	Type of distress	Unit	Quantity	Severity	Extent	Feasible maintenance alternative
1	Pot hole	M2	6	High	low	Patching according to the maintenance standard
2	Asphalt surface damage	M2	30	High	Low	Remove the defected area and resurface
3	Shoving	M2	30	Moderate	Low	Removing the defected area and patch as per the maintenance standard
4	Manhole blockage	%	50	High	High	Clearing debris and trash

As can be seen from the road condition survey data table 2, one can observe that mix design and material characteristics plays an important role in reducing shoving.

4.2.2 Improvement to the existing asphalt pavement distress

On this section of the road same occurrences observed as seen on the section of the road from Imperial Hotel to Gerji, but the different problem observed is the shoving of the asphalt surface this can be caused either by application of excess tack coat on the surface of the asphalt or use of fine grained aggregate, or excess binder content in the asphalt mix. This shoving distress of high severity is resolved by scarifying the surface and re-construction (resurfacing). Furthermore, this problem can be improved by application asphalt mix that suits the road and weather condition, the number and class of traffic.

4.3 From Hanamariam to Kality Total

4.3.1 Existing condition

This sampled road section which starts from Hanamariam Overpass Bridge following the slow lane (outer lane) down to Kality Total passing the square around Kality road and Transport authority of drivers' training center.

As it has been seen on the Hana mariam over Pass Bridge, the road deteriorated and created potholes of high severity and extent as seen on figure-18 and as taken on condition survey data sheet table-3. Furthermore, asphalt damage was also observed and maintained.

This was resulted gutter holes of the bridge that collects and directs the surface runoff towards the down pipes installed on the bridge.

While moving from Hanamariam over pass bridge to Kality road and Transport following the outer lane of the ring road, it is observable that shoving or slippage of the asphalt pavement of high severity and extent was visible as it is seen on figure-15 and also as registered on condition survey data table-3. On some sections of this road, rutting along wheel path was also a phenomenon as observed on figure-15. In addition to this, it has been seen high severity and extent of asphalt surface damage, patch deterioration and pothole on the outer lane of the ring road around the square (Road and transport authority) due to manhole gutter blockage as seen on figure-1and 2 and as taken on the data sheet on table-3.

On the road that extends from Kality Road and Transport Authority (drivers' training center) upto Kality Sheger building, It can be seen that there are patched area deterioration, slope problem of the asphalt surface, drainage problem of the road on both sides and also surface damage observed as shown in figure- 3,4,5,6,7,8 and 10 and also as taken on condition survey data table-4.

In addition to this, the road that directs from Kality Sheger building towards Crown Hotel has tremendous distresses of shoving, depression of some section of the road, pothole Cambering problem, damage and blockage of drainage lines and also complete damage of the road and shoulder as observed on figure-9,11, 16 & 17and also registered on condition survey data sheet table-5. In general the road surface on this section is completely and severely damaged.

Furthermore, raveling of high severity and low extent was a phenomenon around Kality Yetebaberut fuel station. On the road down to Gebriel church, it can be seen that there are also raveling, pothole and patch deterioration visible on the surface of the asphalt pavement. It is also observable rutting of high severity and extent occurred around Kality Total as shown on figure-13 and 14 and also as taken on the data sheet table-6. The slopping and drainage problems were also prominent factors for this.

Figure-1 Photo courtesy of AACRA Blocked Manhole gutter

Figure-2 Photo courtesy of AACRA Patch deterioration from Hana Mariam to Kality Road and Transport authority outer lane Ring road

Figure-3 Photo courtesy of AACRA Propagation of block cracking to pot hole around Kality Road and Transport

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Figure-4 Photo courtesy of AACRA Pot hole drainage and slope problem around Kality Road &Transport authority

Figure-5 Photo courtesy of AACRA around Kality Weha Limat Shoulder damage, Slope problem and Drainage problem

Figure-6 Photo courtesy of AACRA around Kality Weha Limat Slope or cambering problem and no Drainage at all

Figure-7 Photo courtesy of AACRA the road around Korki factory with out drainage and shoulder damage

Figure-8 Photo courtesy of AACRA the road around Korki factory with camber problem and the shoulder level above the road level with no drainage.

Figure-9 Photo courtesy of AACRA The road section from Kality Sheger Building to Kality Crown Hotel completely damaged road with drainage blocked by damage and culvert slab with no access for surface run off entrance and camber problem.

Figure-10 Photo courtesy of AACRA Aging of asphalt on the road section from Kality Road and Transport authority to Kality Sheger building

Figure-11 Photo courtesy of AACRA Drainage damage and blockage on the road section from Kality Sheger Building to Crown Hotel

Figure-12 Photo courtesy of AACRA Surface damage around Kality Total due to Lack of drainage and cambering problem

Figure-13 Photo courtesy of AACRA Rutting of high severity, Structural damage, Shoulder damage and lack of drainage around Kality Total

Figure-14 Photo courtesy of AACRA Complete Road Structural damage, Rutting of high severity Cambering problem Shoulder level above road level and lack of drainage provision around Kality Total.

Figure-15 Photo courtesy of AACRA Rutting and shoving of high severity and cambering problem on the road that directs from Hana mariam to Kality Road & Transport Square on the outer lane of ring road.

Figure-16 Photo courtesy of AACRA Drainage blockage, cambering problem and also surface damage of the road section from kality Sheger building to Crown Hotel

Figure-17 Photo courtesy of AACRA Complete damage of the road section from Kality Sheger building to Kality crown Hotel.

Figure-18 Photo courtesy of AACRA pot hole and asphalt surface damage around Hana mariam over pass bridge

The following tables show the condition survey data based on the segmented sections of the roads.

Table 5 shows condition survey of road section from HanaMariam overpass bridge to Kality square (Road and Transport authority)

Item no.	Type of distress	Unit	Quantity	Severity	Extent	Feasible maintenance alternative
1.0	Shoving	M2	60	High	Low	Removing the defected area and patch as per the maintenance standard
2	Rutting	MM	150	High	High	Removing the defected area and Resurface or Overlay as per the maintenance standard
3	Patch deterioration	M2	4.32	Low	Low	Removing the defected area and patch as per the maintenance standard
4	Manhole gutter blockage	ML	500	High	High	Clearing debris and trash

4.3.2 Improvement to the existing asphalt pavement distress

The problems on this section of the road are many to list shoving or slippage of the asphalt surface due to asphalt mix proportion, excess use of binder content and use of finely grained aggregate.

Furthermore, excess application rate of tack coat which is above the standard specification 0.15 to 0.2 lt per square meter. Therefore, bitumen application rate should be made as per the standard of asphalt maintenance.

On the other hand, Rutting along the wheel path was resulted due to loading of heavy traffic along the same path. Furthermore, the asphalt mix design used in all roads in Addis Ababa are all the same. Therefore, the asphalt mix design to be used should be different up on the road condition, traffic class and weather condition

Table 6 shows condition survey of road section from Road and Transport Authority to Kality Sheger building

Item no.	Type of distress	Unit	Quantity	Severity	Extent	Feasible maintenance alternative
1	Pot hole	M2	9	High	low	Removing the defected area and patch as per the maintenance standard
2	Block cracking	M2	5.45	High	low	Removing the defected area and patch as per the maintenance standard
3	Aging	M2	4.32	High	low	Thin over lay
4	Shoving	M2	30	Low	low	Remove the defected area and resurface

Table 7 shows condition survey data of road section from Kality Sheger building to Crown Hotel

Item no.	Type of distress	Unit	Quantity	Severity	Extent	Feasible maintenance alternative
1	Total asphalt surface damage	M2	Full length	High	High	Reconstruction /Rehabilitation
2	Drainage deficiency on both sides	ML	Full length	HIgh	High	Reconstruction /Rehabilitation
3	Crown slope problem	ML	Full length	High	High	Reconstruction /Rehabilitation
4	Shoulder damage	Ml	Full length	High	High	Reconstruction /Rehabilitation
	Drainage blockage		Full length	High	High	Reconstruction /Rehabilitation

Table 8 shows condition survey of road section data from Kality Gebriel Church to Kality Total.

Item no.	Type of distress	Unit	Quantity	Severity	Extent	Feasible maintenance alternative
1	Rutting	MM	175	High	High	Full depth asphalt rehabilitation work
2	Shoving	M2	100	High	low	Full depth asphalt rehabilitation work
3	Pothole	M2	64	High	low	Patching according to the maintenance standard
4	Aging	M2	150	High	high	Resurfacing
5	Block cracking	M2	60	High	high	Removing the defected area and patching
6	Raveling	M2	48	High	low	Overlaying (resurfacing with thin layer)
7	Drainage deficiency	ML	Full length	High	High	Construction of pipe drainage with manhole and gutter
8	Drainage blockage	ML	Full length	High	High	Clearing debris and trash
9	Slope problem of the road	ML	Full length	High	High	Reconstruction of the surface as per standard slope(2.5%)
10	Shoulder damage	Ml	Full length	High	High	Reconstruction

4.3.3 Improvement to the existing asphalt pavement distress

The problems on this section of the road are many due to the age of the road that is more than 15 years old. slopping or cambering problem, drainage blockage, unevenness of the shoulder surface, Rutting, shoving and raveling are the major problems.

The prominent problem for the occurrence of this is the water action on the asphalt pavement; this is the major cause for asphalt surface damage of the road that directs from Hanamariam ring road outer lane towards the square (Kality Road and Transport authority) on the approach of the square. This was occurred due to drainage blockage by rubbish, slope or camber formation of the road a and also construction of the road without drainage.

There is high number of Average annual daily traffic with high traffic class and loading on the pavement, this is the major cause for the rutting along the wheel path, the occurrence of rutting was not only by heavy traffic loading, but also by failure of underlying layer and also poor mix design or use of bitumen that resists the effect of the loading condition.

The road section from Kality Road and Transport authority to Kality Sheger building need full depth reclamation on some defected spots that are depressed.

The road section that extends from Kality Sheger building to Crown hotel has a problem of structural capacity, cambering problem and absence of drainage, to this effect it is severely damaged and needs complete reconstruction or rehabilitation.

The section of the road from Kality Gebriel to Kality Total; there is raveling of the asphalt surface observed around kality Gebriel and Abyssinia bank, this was caused by

Asphalt binder unable to hold aggregate in place due to use of dusty aggregate, stripping, aged asphalt binder and segregation.

In general, the distress condition from Kality Road and Transport to Kality Total has distresses of high severity and extent, it is mandatory to rehabilitate or reconstruct.

As it has been mentioned from the AACRA's construction director, it has been planned to reconstruct newly and the design of the road is in progress by the selected consultant.

5.0 Result And Discussion

The study sets out to assess the existing asphalt defects and its maintenance on the three selected road samples. According to the study asphalt distresses of different type, severity and extent observed so as to make the study more realistic, interviews were made with the construction director of AACRA, maintenance foreman and bitumen sprayer. The reasons for the occurrence of these problems are listed as follows.

5.1Age of the asphalt road

5.2 Lack of pavement management system (PMS)
5.3 Drainage problems
5.4 Traffic loading
5.5 Asphalt mix problem
5.6 Bitumen application rate
5.7 Slope or camber formation

5.1 Age of the asphalt road

The design life of asphalt road is between 10-15 years which an average of 15 years according to ERA's standard specification 2003 manual and also TRL (Transport research laboratory) 1993 of Road note 31.

The time above 15 years without maintenance or reconstruction makes the asphalt road old. Old roads have different surface defects. Oxidation of asphalt with the air is one of the defects caused with the age of the asphalt; this aging causes the asphalt pavement to lose its ductility and increase its stiffness so as to result in asphalt cracks of different pattern.

Therefore, aging of asphalt was a phenomenon on the section of the road from Hanamariam to Kality total.

This is one of the signal for preventive maintenance applications like chip seal of mixed chips of aggregate and asphalt mixed to be applied based on distress bitumen is to be applied following the crack sealing specification sets on activity 215 of ERA specification 2003.

According to TRL (Transport research laboratory) overseas road note31 Structural design of bitumen surfaced roads A maximum air voids content of 5 per cent is recommended to reduce the potential age hardening of the bitumen but on severe sites the overriding criteria is that a minimum air voids of 3 percent at refusal density should be achieved.

5.2 Pavement Management System(PMS)

Condition survey is part of pavement management system. Pavement management system provides consistent, objective and systematic procedure to determine priorities, schedule, allocating resources, and budgeting for pavement maintenance and rehabilitation.

Pavement management can be applied at two major levels; net work level and project level. The net work level focuses on creating the entire network, whereas project level is specific to a given area that has been identified for potential rehabilitation.

The goal of most PMS is to maximize the effectiveness of pavement maintenance and rehabilitation by using maximum benefit of the available fund.

In general the process of PMS consists of four main components; network inventory, pavement condition evaluation, performance prediction models and planning method (article by OESPM)

The basic components of PMS are:

1.0 Data base

2.0 Retrieval methods

3.0 Analysis Methods

4.0 Updating procedures

The data base is created using field survey and data research to gather information needed for good pavement maintenance decision.

It includes pavement condition survey and rating of the asphalt pavement structural deterioration, surface defects, rid quality, skid resistance, pothole and other distresses.

Data was compiled from record data on pavement width, length, structural sections, maintenance histories, traffic conditions and soil conditions.

The collected data stored in the computer for ease of data base sorting, updating and retrieval.

Condition survey is categorized into two:-

1.0 Manual method

2.0 Automated method

Manual method is done by walking or windshield survey or combination of two.

Automated method is done by modern vehicles which is laser operated for data collection and also installed soft ware for storing and sending the collected data to the central location and also for analyzing the data. This automated equipments are profiler for roughness and rutting, Skid trailer with locked wheel for surface friction, circular track meter (CTM) for macro-texture measurement.

The pavement management system at the network level is not yet started in AACRA, but practiced at the project level.

It has been also determined during the interview that Automated equipments for condition survey purchased and arrived.

5.3 Drainage problem

Asphalt roads of recently built before 10 years have their own drainage of closed pipe provided with manhole at some interval distance so as to receive the surface runoff along the curb, through the gutter of the manhole.

On the other hand, old roads of some collector and access roads built with and without drainage. Though the drainage existed on the old road, it became damaged due to lack of maintenance and also blockage by dumping of trash within the manhole and drainage line, as a result of this draining water pump out of the drainage line and also surface runoff drain on the asphalt pavement.

These are the common phenomenon in our city Addis Ababa in the rainy season.

So as to curb these problems, inspection of drainage lines and manhole to be done periodically and remedial solution to be done before rainy season approaching instead of doing it in the rainy season as it is done currently in Addis Ababa. In addition to this, condition survey should be done on the existing drainage line maintenance of it should be planned. Awareness of the community not to dump rubbish, plastic and others in the drainage line should be created.

5.4 Traffic

Asphalt pavement design also depends on the expected level of traffic.

Axle load studies and traffic counts are essential and primary task for successful design, but it is difficult task according to Transport research laboratory(TRL) of 1993 Overseas Road note 31 Structural design of bitumen surfaced roads.

The deterioration of paved roads by the magnitude of individual wheel loads and number of times these loads are applied. For pavement design purposes it is necessary to consider not only the total number of vehicles that will use the road but also the wheel loads or the axle loads. The load imposed by private cars does not contribute significantly to the structural damage as a result of this the damage on the pavement is minimal. For the purposes of structural design, cars and similar sized vehicles can be ignored and only the total number and the axle loading of the heavy vehicles that will use the road during its design life need to be considered.

Heavy vehicles are defined as those having an unladen weight of 3000 kg or more. So as to determine the total traffic over the design life of the road, the first step is to estimate the baseline traffic flows. The estimate should be the (annual) average daily traffic (ADT) currently using the route, classified into the vehicles, trucks (heavy goods vehicles) and buses.

When we see the road section from Hanamariam to Kality total, though, forensic investigation is mandatory to accurately determine its causes, it is believed that traffic load has a major contribution for its high extent of distress.

5.5 Asphalt mix (asphalt concrete) problem

According to TRL (Transport research laboratory) 1993 Road note 31 structural design of bituminous surfaced roads it defines as a dense, continuously graded mix that depends for its strength on both the interlock between aggregate particles and to a lesser extent, on the properties of the bitumen and filler.

The mix is designed to have low air voids and low permeability to provide good durability and good fatigue behavior but this makes the material particularly sensitive to errors in proportioning, and mix tolerances are therefore very narrow.

The particle size distribution for wearing courses are given in the table 7. This is workable that could not be affected by sever deterioration failures but they are not ideal for conditions of sever loading e.g slow moving heavy traffic and high temperature.

Since the continuous matrix of fine aggregate, filler and bitumen is more than sufficient to fill the voids in the coarse aggregate, the particle to particle contact with in the coarse aggregate and resistance to deformation reduces.

It is common to use Marshal Method to select the design binder content by calculating the mean value of binder content.

Table 9 Particle size distribution for wearing courses

Asphalt concrete surfacing				
		Wearing Courses		
	Mix designation	WC1	WC2	BC1 Base course
1	BS test sieve (mm)	Percentage by mass of total aggregate passing test sieve		
2	28	-	-	100
3	20	100	-	80-100
4	14	80-100	100	60-80
5	5	54-72	62-80	36-56
6	2.36	42-58	44-60	28-44
7	1.18	34-48	36-50	20-34
8	0.6	26-38	28-40	15-27
9	0.3	18-28	20-30	10-20
10	0.15	12-20	12-20	5-13
11	0.075	6-12	6-12	2-6
12	Bitumen content (percent by mass of total mix)	5-7	5.5-7.4	4.8-6.1
13	Bitumen Grade (penetration)	60/70 or 80/100	60/70 or 80/100	60/70 or 80/100
14	Thickness (mm)	40-50	30-40	50-65

In practice the upper limit of marshal blow has been exceeded by 20 percent with no adverse effect.

5.5.1 Design to Refusal density

According to TRL (Transport Research Laboratory) 1993 Overseas Road Note 31 Under severe loading conditions asphalt mixes must be expected to experience significant secondary compaction in the wheel paths. Severe conditions cannot be precisely defined but will consist of a combination of two or more of the following;

- High maximum temperatures
- Very heavy axle loads
- Very channeled traffic
- Stopping or slow moving heavy vehicles

Failure by plastic deformation in continuously graded mixes occurs very rapidly once the VIM are below 3 per cent therefore the aim of refusal density design is to ensure that at refusal there is still at least 3 per cent voids in the mix.

For locations which do not fall into the severe category, the method can be used to ensure that the maximum binder content for good durability is obtained. This may be higher than the Marshall optimum but the requirements for resistance to deformation will be maintained.

The road section from Hanamariam to Kality Total is severely deteriorated by the combination sever loading conditions of very heavy axle loads, very channeled traffic and stopping or slow moving heavy vehicles, therefore the mix design at refusal density is mandatory.

5.6 Bitumen Application rate

Bitumen is a binding agent in the construction of asphalt pavement, it bind unbound macadam road base with the asphalt surface and also binds two asphalt surfaces.

The application of bitumen rated based its use as prime coat and tack coat application, it has been tried to describe these rates based on TRL (Transport research laboratory) 1993 Overseas road note 31 structural design of bituminous surfaced roads

5.6.1 Prime Coat

A prime coat is a thin layer of bitumen sprayed onto the surface of an existing layer, usually of unbound or cement/lime bound material. Its purpose can be summarized as follows:

- It assists in promoting and maintaining adhesion between the road base and the bituminous surfacing by pre-coating the surface of the road base and by penetrating the voids near the surface.
- It helps to seal the surface pores in the road base, thus reducing the absorption of the first spray of bitumen of a surface dressing.
- It helps to bind the finer particles of aggregate together in the surface of the road base.
- If the application of the surfacing is delayed for some reason, it provides the road base with temporary protection against the detrimental effects of rainfall and light traffic.

Low viscosity, medium curing cutback bitumens such as MC-30, MC-70, or in rare circumstances MC-250, can be used for prime coats (alternatively low viscosity road tar can be used if this is available). The depth of penetration should be about 3-10 mm and the quantity sprayed should be such that the surface is dry within two days. The correct viscosity and application rate are dependent primarily on the texture and density of the surface being primed. The application rate is likely to lie within the range 0.3-1 1 kg/m2.

Low viscosity cutbacks are necessary for very dense cement or lime-stabilised surfaces, and high viscosity cutbacks for untreated coarse-textured surfaces. It is usually helpful to spray the surface lightly with water before applying the prime coat as this helps to suppress dust and allows the primer to spread more easily over the surface and to penetrate. Bitumen emulsions are not suitable for priming because they tend to form a skin on the surface.

According to ERA technical specification2003 activity no.314 says spraying a thin layer of heated low viscosity cutback bitumen on to the surface of prepared unbound pavement layer. The purpose is to bind and seal the upper extent of the unbound layer and provide adhesion between this layer and the following layer.

Spraying operation is done by a towed or spray bar pressure distributor

Prime coat shall be applied at between the following temperature ranges:

- 60-80 deg.c for MC-70

- 45-60 deg. C for MC-30

The application rate shall be between 0.3-0.8 litres per square metre(measured at spraying temperature). The spray rate shall be adjusted following trial and finally determined through agreement with the employer’s representative such that the surface becomes dry after 48 hours curing, and bitumen has penetrated between 3-10mm into the surface.

5.6.2 Tack Coat

Tack coat is for tacking the two asphalt surfaces. The primary function of a tack coat is to act as a glue to assist bonding of a new surface layer to a previously primed surface, bituminous road base, or base course that has been left exposed for some time.

Tack coats should be extremely thin and it is appropriate to use a dilute bitumen emulsion spread to give less than 0.2 kg /M2 of residual bitumen with continuous cover.

When temperature conditions are satisfactory, it is possible to obtain a thin layer by lightly spraying the undiluted emulsion with a hand lance and then spreading it with a pneumatic tyred roller to obtain complete coverage.

According to ERA Technical specification 2003, tack coat applied in the range between 0.18-0.2 liters per square meter.

RC-250(Rapid Curing) bitumen shall be heated and applied at a temperature of 80-90 deg.c. In the case of AACRA RC-70 is used as tack coat

When we see the road from Kera to mexico there was a shoving or slipping defect, this was probably due to application of tack coat during maintenance.

5.7 Slope or Camber problem

Camber is important for draining or shedding the surface run off of the asphalt pavement towards the drainage line through the curbstone to the manhole gutter of the drainage line. The cross fall of the camber is called slope.

The roads sampled for study From Emperial Hotel to Gerji has Cambering problem to shed the water towards the side drain as a result of this rain water accumulate on the asphalt surface and this is the cause for the occurrence of pothole.

Furthermore, the section of the road from Kality Road and Transport Authority to Crown Hotel and the road from Kality Gebriel Church to Kality Total has a major camber problem due different reasons.

Therefore, Maintenance is needed to restore a good camber on these roads to enable water to drain off quickly. If there is insufficient camber, water will not drain easily from the surface of the road, potholes will form and the road will deteriorate quickly.

6.0 Conclusion

Improvements are taking place on the modern application of road condition survey which is time saving and cost reduction technologies. Furthermore it gives accurate and reliable data for appropriate maintenance of the asphalt distresses.

In this study, different asphalt distresses and also important pavement management systems (PMS) have been determined.

The existing problems and anticipated causes of these problems have also been determined. Different relevant standards and manuals have been reviewed.

Hence, based on these findings of the study the following conclusion are made :

- Old asphalt roads that were built before 15 years or more have cambering or slope problems.
- The drainages old asphalts need maintenance and rehabilitation.
- Most of the drainage lines and manholes are blocked by trash or rubbish and
- Inspection of manholes and drainage and also clearing trash is done only during the rainy season.
- Asphalt mix (Hot mixed asphalt) produced and used by AACRA for maintenance and new asphalt construction is the same batch (proportion of ingredients) for all roads of traffic category from light to heavy traffic.
- Lack of preventive maintenance application
- Pavement management system and road data base record has not yet started.
- Automated condition survey vehicles are not yet applied.

7.0 Recommendation

Based on the findings of the study, it is required to put forward the following recommendation

7.1 Reconstruction/ Rehabilitation

Old roads need reconstruction so as to reinstate its camber and shed or drain the surface runoff towards the side drain.

7.2 Maintenance

Application of timely (on time) maintenance of asphalt pavement and road side drainages according to the standard technical specification saves high cost incur and road damage by the flood.

7.3Drainage inspection and cleaning

Proper functioning of side drains are important for the well being or extended life of the asphalt road. Therefore, application of drainage inspection and cleaning before commencement of rainy season prevents from flooding and overflow.

7.4 Awareness creation

Many of the drainage lines even recently built damaged due to blockage by trash; this was caused by lack of awareness of the public or road user.

Therefore revolutionary public awareness required by the concerned stack holders.

7.5 Asphalt mix (Hot mixed Asphalt)

Hot mixed asphalt produced for maintenances and construction is done by central plants of AACRA. These plants are already been adjusted to produce the mix of the same batch (proportion) for all roads of low traffic load, Medium and very channeled traffic and very heavy axle load coupled with very channeled and stopping or slow moving heavy vehicles. Therefore, the mix design should be different accordingly.

7.6 Preventive maintenance

Preventive maintenance reduces the deterioration of the roads and also restores its safety and ride ability of pavement before high cost incur.

7.7 Pavement management system

Pavement management is important for overseeing the maintainance and repair of network roads. It offers the potentials for planned and scheduled maintenance.

It further helps for prioritizing roads for maintenance when there is budget constraint.

7.8 Condition Survey

Road condition survey is part of pavement management system that helps to identify the type, severity and extent of the distress.

It is done in two methods

7.8.1 Manual method

7.8.2 Automated Method

The automated method is better and accurate in data collection. Furthermore, it collects, store and retrieve the data when needed, it is also linked with the central computer system through its soft ware program. This automated condition survey equipment is mandatory to ease the maintenance work and reduce the time and also for accuracy of data for decision makers.

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Appendix A

Maintenance is the activities to restore the building to its original shape, colour, and size without changing or replacing the materials to extend its service life.

Repair is the operation that is done to preserve or restore the building to its original condition by replacing the materials decayed or damaged.

Raveling :-the wearing away of the pavement surface caused by the dislodging of aggregate particles.

Longitudinal: - parallel to the centerline of the pavement

Patch :- an area where the pavement has been removed and replaced with a new material.

Polished Aggregate: - surface mortar and texturing worn away to expose coarse aggregate in the concrete

Shoving:-permanent, longitudinal displacement of a localized area of the pavement surface caused by traffic pushing against the pavement.

Pothole: - a bowl-shaped depression in the pavement surface

Water Bleeding:-seepage of water from joints or cracks.

Rutting:-longitudinal surface depressions in the wheel paths.

Reflection Cracking:- the fracture of AC above joints in the underlying jointed concrete pavement layer(s).

Lane-To-Shoulder Drop off: - the difference in elevation between the traffic lane and shoulder.

Block Cracking :-the occurrence of cracks that divide the asphalt surface into approximately rectangular pieces, typically 0.1 m2 or more in size.

Bleeding :-identified by a film of bituminous material on the pavement surface that creates a shiny, glass-like, reflective surface that may be tacky to the touch in warm weather.

Fatigue Cracking: - a series of small, jagged, interconnecting cracks caused by failure of the AC surface under repeated traffic loading (also called alligator cracking)

Interview Questions forwarded to AACRA construction Director, Maintenance Team foreman and Bitumen spreader.

1.0 Is the asphalt mix produced by the central plant and applied for maintenance and construction of all Addis Ababa's roads the same ?

2.0 Is tack coat and prime coat application gauged for compliance with the standard?

3.0 Is there number of pass limitation while compaction of the laid hot mixed asphalt?

4.0 What are the Temperatures limits for Steel and Pneumatic roller compaction start ?

5.0 Are Operators aware of compaction procedure ?

6.0 Is there any assigned person to check the temperature and permit for compaction of steel and tyre Roller on the laid asphalt mix ?

7.0 Do you use small plate compactors for small patch ?

8.0 Is there any patched area left for secondary compaction (Traffic compaction) ?

9.0 Is there any pavement management department ?

10. What measures do you use for prioritizing maintenance ?

11.0 Do you do condition survey ?

if yes... what type of survey Automated or manual ?

12.0 Do you have automated equipment for condition survey ?

13.0 Do you do road inventory at the network level ?

14. Do you plan maintenance activity ?

if yes… What type of maintenance Preventive, corrective or Emergent

15.0 Do you do inspection of Drainage line ?

16.0 When do you do drainage line cleaning and at what interval of time ?